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Victor Duxbury, et al

Lowell Technological Institute Research Foundation
Lowell, Massachusetts

September 1969

TECHNICAL REPORT
70-31-CE

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by

Victor Duxbury

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and

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Contract DAAG-17-68-C-0039

September 1969

UNITED STATES ARMY
NATICK LABORATORIES
Natick - Massachusetts 01760

Clothing and Personal Life Support Equipment
Laboratory
TS-168

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Clothing and Personal Life Support Equipment Laboratory
U. S. ARMY NATICK LABORATORIES
Natick, Massachusetts 01760

FOREWORD

This final report represents the work done by the Lowell Technological Institute Research Foundation under Contract DAAG17-68-C-0039 to develop a lightweight, bulky batting-type filling material for sleeping bags. The report summarizes the accomplishments during the contract period October 1967 to October 1968. The work was performed under Project No. 1J664713D547, Individual Combat Clothing and Equipment Development. Project Officer for the U. S. Army Natick Laboratories was Mr. George Cohen.

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ABSTRACT

An investigation of lightweight, bulky batting-type filling material for sleeping bags involved the study of a wide range of fiber types, which were formed into webs by carding, garnetting and air-layering systems. The resultant webs were subsequently processed into battings by spray-bonding and needling. Needled battings were found to have a consistently greater bulk density than spray-bonded battings formed from corresponding webs.

From considerations of compressional recovery, low bulk density and resistance to laundering, polyester fibers in general were found to be the most satisfactory of all fibers examined, when spray-bonded with acrylic emulsions of the types Nyanza T-15, Tecpol 115 or Rhoplex HA-16. In particular, a blend of 90 percent mechanically crimped Dacron Fiberfil and 10 percent regular Dacron Type 88 Fiberfil showed promise as a filling for sleeping bags. However, practical problems were encountered when battings in excess of 3 oz/sq yd were required to be processed. A blend of 75 percent 4.5 denier Kodel and 25 percent 15 denier Kodel, and a batting of 100 percent regular Dacron Type 88 Fiberfil also showed promise and could be produced without much difficulty at the four weights specified, namely, 2, 3, 4, 5 ounces per square yard.

Picker blending followed by carding was found to be a satisfactory method of web formation, as air-laid battings tended to show a greater loss of thickness after laundering. Thickness loss after laundering was also found to be influenced by the batting weight per unit area. The lighter battings generally shrank to a greater extent than the heavier battings. However, for sleeping bag applications, multi-layering of battings is required to obtain a final thickness of approximately 2 inches at 0.01 psi pressure. Under these circumstances, loss in thickness after laundering is inhibited; in one instance a trial sleeping bag was found to have increased in thickness after laundering.

DEVELOPMENT OF LIGHTWEIGHT, BULKY BATTING-TYPE FILLING MATERIAL FOR SLEEPING BAGS

1. Introduction

Sleeping bags filled with a mixture of waterfowl feathers and down have been used by the U. S. Armed Forces since World War II. There have been occasions when the available supply of this material was insufficient to meet the demand. In addition, the use of feathers and down presents certain difficulties in the manufacture of sleeping bags. These difficulties could be eliminated if a substitute could be supplied in a continuous form at convenient widths. Accordingly, a program has been underway for some time at the U. S. Army Natick Laboratories to develop other filling materials.

The work carried out at the U. S. Army Natick Laboratories indicated that batting-type filling materials could be developed as a suitable filler for sleeping bags. The prerequisites for a successful product are a high bulk-to-weight ratio, a readily launderable material whose properties would remain relatively unchanged, a reasonable degree of flexibility and excellent recovery from compressive strain.

The scope of work was designed to investigate various types of fibers in several deniers and staple lengths, both singly and in blends. A comparison of methods of manufacturing the battings and the use of different bonding agents was included in the study.

It was considered desirable to carry out an initial laboratory screening process and to select from the results a range of promising materials for further investigation on production-scale equipment. After suitable evaluation, the most successful types were to be chosen for the final submission of bulk yardage.

2. Laboratory Processing and Initial Screening

A total of 92 laboratory sample battings were prepared from various fibers singly and in combination by different methods of manufacture. The fibers employed are detailed in Table I.

Web formation was by means of a sample Davis and Furber woolen card. The resulting webs were formed into battings approximately 2 inches thick. Battings were constructed as follows:

a. Unidirectional, superimposed webs

b. Cross-laid webs

The resultant battings were then evaluated:

a. In their untreated state

b. After needling by a James Hunter "Fiber Locker"

c. After spray-bonding

Additional battings prepared by means of commercial garnetting and air-layering systems were evaluated after needling and spray-bonding.

The initial screening process consisted of a determination of weight per unit area by means of weighing four inch by four inch samples. These samples were then measured for thickness by applying predetermined incremental weights to give pressures of 0.01, 0.05, 0.1, 0.2, 0.5 and 1.0 psi and determining their thicknesses at the various loads by means of a cathetometer. The weights were then progressively removed and thickness measurements made to determine the specimen's ability to recover from compressive loading.

Bulk density was calculated for the specimens at various loads by dividing the weight of the sample by its volume. The results were compared with those obtained from down and feathers, and if they were similar the specimen was considered promising.

Stiffness was examined in a somewhat arbitrary fashion by placing the center of the specimen on a pencil held horizontally and noting the bending characteristic.

The specimens which showed promise were then laundered in accordance with Government Specification No. MIL-B-41826B dated 12 May 1966 and were again measured for thickness and bulk density.

TABLE I. FIBER TYPES USED IN SAMPLES FOR INITIAL SCREENING AND METHODS OF BATTING PREPARATION

Fiber Types			
Carded Webs	Untreated	Spray-Bonded	Needled
Acrylic 3 denier 2 in.	x	x	x
Nylon 5 denier 3 in. (multilobal)	x		
Fiberglas Beta type 1.5 in.	x	x	x
Polypropylene 5 denier 3 in.	x	x	x
Wool 40s quality shrink resistant	x	x	x
Dacron (mechanically crimped) Fiberfil	x	x*	x
Dacron Type 88 Fiberfil	x	x*	x
Dacron Type 64 12 denier 1.5 in.	x	x*	x
Kodel 4.5 denier 2 in.	x	x*	x
Kodel 15.0 denier 1.5 in.	x	x*	x
Kodel 25.0 denier 3 in.	x	x*	x
Serene continuous filament (Fortrel 7)		x	x
Kodel 75% 4.5 denier; 25% 15 Denier	x	x**	x
Kodel 60% 4.5 denier; 40% 15 denier	x	x	x
Kodel 50% 4.5 denier; 50% 15 denier	x	x	x
Kodel 40% 4.5 denier; 60% 15 denier	x	x	x
Kodel 25% 4.5 denier; 75% 15 denier	x	x	x
Kodel 75% 4.5 denier; 25% 25 denier	x	x	x
Kodel 50% 4.5 denier; 50% 25 denier	x	x	x
Kodel 25% 4.5 denier; 75% 25 denier	x	x	x
Kodel 75% 15 denier; 25% 25 denier	x	x	x
Garnetted Webs			
Nylon 5 denier 3 in. (multilobal)	x	x	x
Nichols polyester 6 denier 2 in.	x	x	x
Air-laid Webs			
Nylon 5 denier 3 in. (multilobal)	x	x	x
Nichols polyester 6 denier 2 in.	x	x***	x

* With four different spray-bonding treatments
** Three spray-bonding treatments
*** Two spray-bonding treatments

3. Results of Initial Screening Trials

Of all fibers examined, polyester gave superior results and various deniers of polyester blended together gave results at least equal to Dacron Type 88 Fiberfil battings.

The method of web formation did not appear to influence the ability of a batting to recover from compression; carding, garnetting or air-laying were equally satisfactory before laundering.

However, there were indications that after laundering, air-laid battings did not recover to the same extent as carded battings (this tendency was subsequently confirmed on commercially produced samples). Unidirectional or cross-laid webs did not reveal any significant differences in batting behavior under test.

Untreated battings, i.e., battings which were neither needled nor spray-bonded, proved unsatisfactory, particularly after laundering.

Needled battings showed, for a given thickness, a consistently greater weight per unit area than spray-bonded battings. There was also a greater tendency for needled battings to shrink after laundering.

Spray bonding agents gave varying results. The three which proved most satisfactory and equal in their results were Rhoplex HA-16, Nyanza T-15 and Tecpol 115, when used in conjunction with the manufacturer's recommended catalysts.

4. Commercial Sample Manufacture

a. Carded Battings

Table II gives details of six samples consisting of various fibers, fiber blends and bonding agents prepared by the carding process and selected on the basis of screening trial results.

Four double-doffer worsted-type cards equipped with metallic wire and arranged in tandem were employed to produce the six battings, each approximately 90 yards long with a nominal weight range of 2.5 to 3.0. ounces per square yard.

The battings were spray-bonded on one side and passed through the base of a curing oven at a temperature of 275°F and a speed of approximately 10 yards per minute. The battings were then reversed, spray-bonded on the opposite side and passed through the upper section of the curing oven at a temperature of 350°F and a speed of approximately 10 yards per minute.

TABLE II. COMMERCIALLY CARDED BATTINGS, FIBER COMPONENTS AND BINDERS

Sample No.	Fiber Components	Spray-Bonding Agents	Loss in Thickness After Laundering Measured at 0.01 psi (%)	Comments
T-986	100% Nichols polyester, 6 denier, 2 in.	15% Tecpol 115 with 1% oxalic acid	9	--
T-987	As for T-986	12.5% Nyanza T-15 with 1% Melamine and 1% ammonia	11	--
T-988	75% Kodel 4.5 denier 2.0 in. Type IV Bright 25% Kodel 15.0 denier, 1.5 in. Type IV, Bright	12.5% Nyanza T-15 with 1% ammonia	11	Picker Blended
T-989	As for T-988	15% Tecpol 115 with 1% oxalic acid	7	Picker Blended
T-990	100% Dacron Fiberfil Type 88	12.5% Nyanza T-15 with 1% ammonia	11	--
T-991	90% mechanically crimped Dacron Fiberfil 10% regular Dacron Type 88 Fiberfil	12.5% Nyanza T-15 with 1% ammonia	$>$ 20	Unsatis-factory Carding

Carding was satisfactory for all samples except T-991 (90 percent mechanically crimped Dacron Fiberfil, 10 percent regular Dacron Type 88 Fiberfil), which was found to load the card wire, form pills and produce an uneven "pilly" web. This sample failed the thickness-retention test after laundering. However, a subsequent laundering test conducted at the U. S. Army Natick Laboratories indicated satisfactory thickness retention, although at a lower level than the other samples. It should be noted in this context that samples laundered at the Lowell Laboratories showed a consistently greater loss of thickness than corresponding samples laundered at the U. S. Army Natick Laboratories. An exchange of samples indicated that the measurement of loss of thickness was in close agreement, and it was therefore concluded that differences in laundering and/or drying equipment were responsible for the difference in results.

The six carded battings were evaluated by the U. S. Army Natick Laboratories by the standard method except that four thicknesses of batting were combined to form a sample sleeping bag. Thickness, bulk density before laundering, and thickness and shrinkage after laundering were measured. Each sample was laundered twice by the "wool" wash procedure which is a low-temperature wash used for sleeping bags. The results are given in Table III.

All six commercial samples showed promise and it was decided to prepare experimental sleeping bags from five of them (T-987 through T-991) before proceeding with the larger quantity of batting for final submission.

b. Air-laid Battings

Table IV gives details of two samples prepared on the Rando-Web equipment and spray-bonded and cured in a manner similar to the carded battings described previously.

These samples were evaluated at the U. S. Army Natick Laboratories in the same way as the carded battings; results are given in Table V.

Both samples were considerably reduced in thickness after laundering and it was considered inadvisable to proceed further with this method of manufacture.

TABLE [illegible]II. COMMERCIALLY CARDED BATTING SAMPLES BEFORE AND AFTER LAUNDERING

Sample No.	Batting Weight (oz/yd^2)	Weight* (oz/yd^2)	Bulk Density (lb/ft^3)		Thickness (in.) at two loads*				% Loss in Thickness After Laundering*		% Shrinkage After Laundering*	
					Before laundering		After laundering					
			0.002 psi	0.01 psi	0.002 psi	0.01 psi	0.002 psi	0.01 psi	0.002 psi	0.01 psi	Length	Width
T-986	2.49	10.0	0.44	0.49	1.88	1.68	1.77	1.58	5.9	6.0	5.1	3.0
T-987	2.75	11.0	0.46	0.52	2.00	1.77	1.97	1.77	1.5	0.0	2.8	7.0
T-988	3.14	12.6	0.52	0.60	2.01	1.75	1.95	1.68	3.0	4.0	3.5	3.3
T-989	2.50	10.0	0.37	0.41	2.25	2.02	2.19	1.92	2.7	5.0	2.6	4.5
T-990	2.58	10.3	0.41	0.46	2.10	1.87	2.02	1.72	3.8	8.0	3.6	4.5
T-991	2.48	9.9	0.38	0.44	2.16	1.87	2.08	1.77	3.7	5.3	3.0	3.0

* four superimposed batting layers

TABLE IV. COMMERCIALLY AIR-LAID BATTINGS, FIBER COMPONENTS AND BINDERS

Sample No.	Fiber Components	Spray-Bonding Agents	Loss in Thickness after Laundering Measured at 0.01 psi
T-994	100% Nichols Polyester 6 denier 2.0 in.	12.5% Tecpol 115 with 1% oxalic acid	> 20%
T-995	Same as for T-994	12.0% Nyanza T-15 with 1% ammonia	> 20%

TABLE V. COMMERCIALLY AIR-LAID BATTING SAMPLES BEFORE AND AFTER LAUNDERING

Sample No.	Batting Weight (oz/yd^2)	Weight* (oz/yd^2)	Bulk Density (lb/ft^3)		Thickness (in.) at two loads*				% Loss in Thickness After Laundering*		% Shrinkage After Laundering*	
					Before laundering		After laundering					
			0.002 psi	0.01 psi	0.002 psi	0.01 psi	0.002 psi	0.01 psi	0.002 psi	0.01 psi	Length	Width
T-994	2.89	11.6	0.47	0.51	2.05	1.89	1.68	1.51	18.0	20.1	3.4	4.6
T-995	2.81	11.2	0.49	0.57	1.83	1.65	1.54	1.34	15.8	18.8	3.1	4.0

* four superimposed batting layers

5. Experimental Sleeping Bags

Arrangements were made to manufacture sleeping bags from the five selected commercially carded battings. These were evaluated before and after two wool launderings at the U. S. Army Natick Laboratories. The results are given in Table VI. Insulation values were determined in CLO* units for some of the sleeping bags; these are recorded together with comparative evaluation particulars of a standard down and feather-filled bag.

TABLE VI. SLEEPING BAG EVALUATION DATA

Sleeping Bag No.	Filling Material: Sample No.	Filling Material: Weight (oz/yd^2)	Total Bag Weight (lb-oz)	Cubage* Bag (ft^3)	Thickness (in.) at two loads, and CLO values*: Before Laundering 0.002 psi	Before Laundering 0.01 psi	Before Laundering CLO	After Laundering 0.002 psi	After Laundering 0.01 psi	After Laundering CLO
A-18**	Down & Feathers	13.0	6-2	0.70	1.98	1.32	5.34	2.50	2.16	***
A-5	T-987	11.0	5-9	0.81	1.22	0.98	--	1.34	1.07	--
A-6	T-988	12.6	5-13	0.85	1.49	1.20	4.99	1.27	1.00	4.79
A-7	T-989	10.0	5-11	0.78	1.52	1.27	--	1.17	0.96	--
A-8	T-990	10.3	5-13	0.70	1.30	1.07	5.03	1.22	1.01	--
A-9	T-991	9.9	5-8	0.95	1.59	1.28	4.71	1.46	1.17	4.77

* See Appendix for description of cubage and CLO values

** A-18 represents standard M-1949 mountain sleeping bag filled with a blend of 18% down and 82% waterfowl feathers.

*** The CLO value after laundering of the standard down and feather-filled bag was not determined. However, evaluation of similar bags has shown increase in CLO values of approximately 3 percent after laundering.

Considering that the sleeping bags prepared with batting-type filling materials had lower weights of filling than the standard down and feather bag, the CLO values obtained are comparable on an equal-weight basis. It was decided to prepare larger quantities of T-988, T-990 and T-991 for further evaluation. This selection was made because it was felt that further evaluation of three different types of batting would give the most information.

*See Appendix

6. Manufacture of Final Lengths of Batting

It was intended that four battings should be produced weighing two, three, four, five oz/sq yd, respectively, in each of the three samples, T-988, T-990 and T-991. However, it was found to be impractical to produce Sample T-991 in weights greater than two and three ounces per square yard. The card wire loaded excessively as in the previous trial and batting weights in excess of three oz/sq yd could not be manufactured on the equipment available.

Spraying of the resin binder (12.5 percent Nyanza T-15 and 1 percent ammonia) was done by means of two sections each of three spray guns, one section being situated at the front of the machine and the other at the rear. For the 2 and 3 oz/sq yd battings, the spray guns were set at a distance of 21 inches above the batting surface, and for 4 and 5 oz/sq yd batting, 18 inches above the batting surface. Fine spraying nozzles were used for the 2 and 3 oz/sq yd battings and coarser nozzles were used for the 4 and 5 oz/sq yd battings.

The battings were sprayed on one side and passed through the lower drying chamber at 240°F. This procedure was followed by spraying on the reverse side and passing through the upper drying chamber for drying and curing at 325°F. Other details are given in Table VII.

TABLE VII. SPRAY GUN PRESSURES AND DRYING CHAMBER FAN SPEEDS

Batting Weight (oz/yd^2)	Pressure Applied at Spray Gun (psi)	Drying Chamber Fan Speeds (rpm)
2	30	1000
3	35	1200
4	44	1300
5	50	1400

7. Testing the Final Lengths of Batting

The production samples were tested for thickness, compressional recovery, and launderability in accordance with Military Specification MIL-B-41826B.

The initial thickness and compressional recovery values were determined as noted in MIL-B-41826B on single layers of batting; the thickness

"after compression" was obtained by loading the specimens to 5 psi, maintaining this load for 60 seconds, removing the load and allowing it to recover for 300 seconds. Testing was performed using an Instron CRE Tester.

Specimens were laundered at the U. S. Army Natick Laboratories as noted in MIL-B-41826B, using single thicknesses of batting. The battings were then tested for initial thickness, compressional recovery and thickness "after compression" as noted above.

The average thickness results are listed in Tables VIII through XVII. The compressional recovery values are listed in Table XVIII.

The specimens which were cut for laundering (24 x 24 in.) were weighed to determine the initial batting weight. Five 2 x 2 inch squares were cut from each laundered specimen to determine the batting weight after laundering. The batting weights are listed in Table XIX.

The bulk density for each sample was determined by dividing the weight (lb/sq ft) by the thickness (ft). These results are listed in Tables XX through XXIX.

It will be noted that for all 10 samples, the thickness of the single layers of laundered specimens measured at a pressure of 0.01 psi is considerably lower than that of the corresponding unlaundered samples. These specific samples had been selected because of their ability to retain a large portion of their unlaundered bulk. Table III, however, shows that the maximum loss in thickness had been 8.0 percent for sample T-990 when laundered in four layers of batting arranged to produce a total thickness of approximately two inches.

It appears, therefore, that single layers of spray-bonded batting exhibit a much greater tendency to shrink in thickness during laundering than the same battings arranged in multiple layers.

It also appears that the lower the initial weight per unit area of the single layer, the greater the tendency to shrink in thickness during laundering.

TABLE VIII. THICKNESS, INCH, T-990, 2 OUNCE

Load Applied (psi)	As Received Initial	As Received After Compression	Laundered Initial	Laundered After Compression
0.005	0.540	0.466	0.271	0.244
0.010	0.472	0.404	0.239	0.217
0.015	0.434	0.361	0.244	0.202
0.025	0.374	0.309	0.204	0.184
0.050	0.283	0.226	0.173	0.155
0.100	0.196	0.150	0.141	0.124
0.150	0.150	0.113	0.121	0.106
0.200	0.122	0.090	0.106	0.091
0.500	0.055	0.042	0.058	0.048
1.000	0.030	0.024	0.033	0.027
2.000	0.017	0.015	0.017	0.015
4.000	0.010	0.008	0.008	0.009

TABLE IX. THICKNESS, INCH, T-990, 3 OUNCE

Load Applied (psi)	As Received Initial	As Received After Compression	Laundered Initial	Laundered After Compression
0.005	0.685	0.604	0.395	0.350
0.010	0.601	0.529	0.358	0.321
0.015	0.547	0.478	0.337	0.302
0.025	0.476	0.414	0.311	0.279
0.050	0.367	0.312	0.270	0.241
0.100	0.254	0.212	0.225	0.198
0.150	0.098	0.163	0.197	0.171
0.200	0.159	0.130	0.174	0.150
0.500	0.080	0.062	0.104	0.085
1.000	0.047	0.038	0.062	0.057
2.000	0.028	0.023	0.036	0.031
4.000	0.017	0.015	0.021	0.021

TABLE X. THICKNESS, INCH, T-990, 4 OUNCE

Load Applied (psi)	As Received Initial	As Received After Compression	Laundered Initial	Laundered After Compression
0.005	0.792	0.700	0.426	0.381
0.010	0.724	0.634	0.388	0.350
0 015	0.677	0.587	0.367	0.331
0.025	0.613	0.521	0.320	0.305
0.050	0.497	0.407	0.298	0.266
0.100	0.365	0.306	0.253	0.222
0.150	0.289	0.223	0.224	0.194
0.200	0.237	0.179	0.201	0.192
0.500	0.112	0.071	0.126	0 102
1.000	0.059	0.045	0.078	0.063
2.000	0.033	0.026	0.049	0.040
4 000	0.018	0.016	0.029	0.027

TABLE XI. THICKNESS, INCH T-990, 5 OUNCE

Load Applied (psi)	As Received Initial	As Received After Compression	Laundered Initial	Laundered After Compression
0.005	0.876	0.781	0.592	0.526
0.010	0.809	0.717	0.537	0.484
0.015	0.765	0.672	0.513	0.459
0.025	0.703	0.610	0.478	0.409
0.050	0.593	0.499	0.424	0.378
0.100	0.459	0.362	0.366	0.322
0.150	0.377	0.279	0.329	0.286
0.200	0.316	0.246	0.300	0.258
0.500	0.161	0.124	0.198	0.162
1.000	0.093	0.075	0.127	0.106
2.000	0.057	0.049	0.081	0.074
4.000	0.037	0.034	0.056	0.053

TABLE XII. THICKNESS, INCH, T-988, 2 OUNCE

Load Applied (psi)	As Received Initial	As Received After Compression	Laundered Initial	Laundered After Compression
0.005	0.633	0.523	0.237	0.215
0.010	0.543	0.445	0.215	0.196
0.015	0.486	0.395	0 203	0.184
0.025	0.418	0.333	0.187	0.171
0.050	0.311	0.241	0.163	0.148
0.100	0.213	0.161	0.137	0.123
0.150	0.165	0.123	0.120	0.106
0.200	0.135	0.099	0.106	0.094
0.500	0.064	0.046	0.063	0.053
1.000	0.036	0.028	0.036	0.032
2.000	0.021	0.017	0.019	0.018
4.000	0.013	0.010	0.010	0.012

TABLE XIII. THICKNESS, INCH T-988, 3 OUNCE

Load Applied (psi)	As Received Initial	As Received After Compression	Laundered Initial	Laundered After Compression
0.005	0.753	0.647	0.369	0.328
0.010	0.659	0.554	0.334	0.299
0.015	0.599	0.491	0.314	0.283
0.025	0.521	0.427	0.290	0.258
0.050	0.405	0.321	0.253	0.224
0.100	0.282	0.217	0.212	0 186
0.150	0.223	0.168	0.187	0.181
0 200	0.179	0.136	0.167	0.142
0.500	0.093	0.064	0.101	0.082
1.000	0.048	0.038	0.061	0.050
2.000	0.029	0.025	0.035	0.033
4.000	0.019	0 017	0.021	0.020

TABLE XIV. THICKNESS, INCH, T-988, 4 OUNCE

Load Applied (psi)	As Received Initial	As Received After Compression	Laundered Initial	Laundered After Compression
0.005	0.922	0.808	0.477	0.422
0.010	0.831	0.725	0.434	0.386
0.015	0.772	0.663	0.410	0.366
0.025	0.695	0.587	0.381	0.339
0.050	0.566	0.460	0.333	0.294
0.100	0.417	0.320	0.281	0.244
0.150	0.332	0.254	0.249	0.214
0.200	0.275	0.207	0.223	0.191
0.500	0.134	0.098	0.139	0.113
1.000	0.074	0.057	0.086	0.070
2.000	0.044	0.037	0.052	0.043
4.000	0.027	0.026	0.033	0.031

TABLE XV. THICKNESS, INCH, T-988, 5 OUNCE

Load Applied (psi)	As Received Initial	As Received After Compression	Laundered Initial	Laundered After Compression
0.005	0.889	0.786	0.604	0.536
0.010	0.823	0.721	0.550	0.490
0.015	0.780	0.676	0.518	0.461
0.025	0.717	0.612	0.479	0.426
0.050	0.623	0.498	0.417	0.367
0.100	0.467	0.369	0.353	0.305
0.150	0.383	0.293	0.313	0.268
0.200	0.324	0.249	0.280	0.236
0.500	0.163	0.119	0.177	0.145
1.000	0.091	0.070	0.115	0.095
2.000	0.053	0.046	0.073	0.063
4.000	0.033	0.030	0.051	0.048

TABLE XVI. THICKNESS, INCH, T-991, 2 OUNCE

Load Applied (psi)	As Received		Laundered	
	Initial	After Compression	Initial	After Compression
0.005	0.538	0.468	0.267	0.243
0.010	0.460	0.396	0.238	0.215
0.015	0.413	0.354	0.217	0.199
0.025	0.344	0.294	0.197	0.183
0.050	0.262	0.210	0.164	0.148
0.100	0.176	0.136	0.130	0.114
0.150	0.135	0.102	0.110	0.095
0.200	0.108	0.081	0.094	0.081
0.500	0.044	0.038	0.047	0.038
1.000	0.030	0.023	0.026	0.021
2.000	0.019	0.014	0.014	0.011
4.000	0.012	0.008	0.007	0.006

TABLE XVII. THICKNESS, INCH, T-991, 3 OUNCE

Load Applied (psi)	As Received		Laundered	
	Initial	After Compression	Initial	After Compression
0.005	0.771	0.688	0.431	0.392
0.010	0.693	0.607	0.387	0.352
0.015	0.636	0.549	0.360	0.327
0.025	0.561	0.471	0.328	0.298
0.050	0.428	0.343	0.276	0.247
0.100	0.293	0.224	0.220	0.193
0.150	0.223	0.166	0.186	0.162
0.200	0.177	0.131	0.160	0.134
0.500	0.077	0.055	0.085	0.070
1.000	0.033	0.029	0.050	0.042
2.000	0.019	0.014	0.030	0.026
4.000	0.008	0.007	0.018	0.014

TABLE XVIII. COMPRESSIONAL RECOVERY, PERCENT
(at 0.010 psi)

Sample	As Received	After Laundering
T-990 2 oz	85.6	90.8
T-990 3 oz	88.0	89.7
T-990 4 oz	87.6	90.2
T-990 5 oz	88.6	90.1
T-988 2 oz	92.0	91.2
T-988 3 oz	84.1	89.5
T-988 4 oz	87.2	88.9
T-988 5 oz	87.6	98.1
T-991 2 oz	86.1	90.3
T-991 3 oz	87.6	91.0

TABLE XIX. BATTING WEIGHT, OUNCES PER SQUARE YARD

Sample	Initial	Laundered
T-990 2 oz	2.05	2.17
T-990 3 oz	3.60	3.56
T-990 4 oz	3.86	4.50
T-990 5 oz	5.40	5.72
T-988 2 oz	2.06	2.28
T-988 3 oz	3.59	3.59
T-988 4 oz	4.11	4.29
T-988 5 oz	4.88	5.02
T-991 2 oz	2.06	2.08
T-991 3 oz	2.83	3.04

TABLE XX. BULK DENSITY, LB/CU FT, T-990, 2 OUNCE

Load Applied (psi)	As Received Initial	As Received After Compression	Laundered Initial	Laundered After Compression
0.005	0.32	0.37	0.67	0.74
0.010	0.36	0.42	0.76	0.83
0.015	0.39	0.47	0.81	0.90
0.025	0.46	0.55	0.89	0.98
0.050	0.60	0.76	1.05	0.17
0.100	0.87	1.14	1.28	1.46
0.150	1.14	1.51	1.50	0.71
0.200	1.40	1.90	1.71	1.99
0.500	3.11	4.07	3.12	3.77
1.000	5.70	7.13	5.49	6.70
2.000	10.06	11.40	10.65	12.07
4.000	17.10	21.38	22.63	20.11

TABLE XXI. BULK DENSITY, LB/CU FT, T-990, 3 OUNCE

Load Applied (psi)	As Received Initial	As Received After Compression	Laundered Initial	Laundered After Compression
0.005	0.44	0.50	0.75	0.85
0.010	0.50	0.57	0.83	0.93
0.015	0.55	0.63	0.88	0.98
0.025	0.63	0.72	0.96	1.06
0.050	0.82	0.96	0.10	1.23
0.100	1.18	1.42	1.32	1.50
0.150	1.52	1.84	1.51	1.74
0.200	1.89	2.31	1.71	1.98
0.500	3.75	4.84	2.86	3.49
1.000	6.38	7.89	4.79	5.21
2.000	10.71	13.04	8.25	9.58
4.000	17.65	20.00	14.14	14.14

TABLE XXII. BULK DENSITY, LB/CU FT, T-990, 4 OUNCE

Load Applied (psi)	As Received Initial	As Received After Compression	Laundered Initial	Laundered After Compression
0.005	0.41	0.46	0.88	0.98
0.010	0.45	0.51	0.97	1.07
0.015	0.48	0.55	1.02	1.13
0.025	0.53	0.62	1.17	1.23
0.050	0.65	0.79	1.26	1.41
0.100	0.88	1.05	1.48	1.69
0.150	1.11	1.44	1.67	1.93
0.200	1.36	1.80	1.87	1.95
0.500	2.88	4.54	2.98	3.68
1.000	5.46	7.16	4.81	5.95
2.000	9.76	12.38	7.65	9.37
4.000	17.89	20.13	12.93	13.89

TABLE XXIII. BULK DENSITY, LB/CU FT, T-990, 5 OUNCE

Load Applied (psi)	As Received Initial	As Received After Compression	Laundered Initial	Laundered After Compression
0.005	0.51	0.58	0.81	0.91
0.010	0.56	0.63	0.89	0.99
0.015	0.59	0.67	0.93	1.04
0.025	0.64	0.74	1.00	1.17
0.050	0.76	0.90	1.13	1.26
1.000	0.98	1.24	1.30	1.48
0.150	1.19	1.61	1.45	1.67
0.200	1.42	1.83	1.59	1.85
0.500	2.80	3.63	2.43	2.94
1.000	4.84	6.00	3.76	4.50
2.000	7.90	9.18	5.89	6.45
4.000	12.16	13.24	8.52	9.00

TABLE XXIV. BULK DENSITY, LB/CU FT, T-988, 2 OUNCE

Load Applied (psi)	As Received		Laundered	
	Initial	After Compression	Initial	After Compression
0.005	0.27	0.33	0.80	0.88
0.010	0.32	0.39	0.88	0.97
0.015	0.35	0.44	0.94	1.03
0.025	0.41	0.52	1.02	1.11
0.050	0.55	0.71	1.17	1.28
0.100	0.81	1.07	1.39	1.55
0.150	1.04	1.40	1.58	1.79
0.200	1.27	1.73	1.79	2.02
0.500	2.69	3.74	3.02	3.59
1.000	4.78	6.14	5.28	5.94
2.000	8.19	10.12	10.00	10.56
4.000	13.23	17.20	17.20	15.83

TABLE XXV. BULK DENSITY, LB/CU FT, T-988, 3 OUNCE

Load Applied (psi)	As Received		Laundered	
	Initial	After Compression	Initial	After Compression
0.005	0.40	0.46	0.81	0.91
0.010	0.45	0.54	0.90	1.00
0.015	0.50	0.61	0.95	1.06
0.025	0.57	0.70	1.03	1.16
0.050	0.74	0.93	1.18	1.34
0.100	1.06	1.38	1.41	1.61
1.150	1.34	1.78	1.60	1.86
0.200	1.67	2.20	1.79	2.11
0.500	3.22	4.67	2.96	3.65
1.000	6.23	7.87	5.90	5.98
2.000	10.31	11.96	8.54	9.06
4.000	15.74	17.59	14.24	14.95

TABLE XXVI. BULK DENSITY, LB/CU FT, T-988, 4 OUNCE

Load Applied (psi)	As Received Initial	As Received After Compression	Laundered Initial	Laundered After Compression
0.005	0.37	0.42	0.75	0.85
0.010	0.41	0.47	0.82	0.93
0.015	0.44	0.52	0.87	0.98
0.025	0.49	0.58	0.94	1.06
0.050	0.61	0.75	1.08	1.22
0.100	0.82	1.07	1.27	1.47
0.150	1.03	1.35	1.44	1.67
0.200	1.25	1.66	1.61	1.87
0.500	2.56	3.50	2.58	3.17
1.000	4.64	6.02	4.16	5.11
2.000	7.80	9.27	6.88	7.96
4.000	12.70	13.19	10.85	11.55

TABLE XXVII. BULK DENSITY, LB/CU FT, T-988, 5 OUNCE

Load Applied (psi)	As Received Initial	As Received After Compression	Laundered Initial	Laundered After Compression
0.005	0.46	0.52	0.69	0.78
0.010	0.49	0.56	0.76	0.85
0.015	0.52	0.60	0.81	0.91
0.025	0.57	0.67	0.87	0.98
0.050	0.65	0.82	1.00	1.14
0.100	0.87	1.10	1.18	1.37
0.150	1.06	1.39	1.34	1.56
0.200	1.26	1.63	1.49	1.77
0.500	2.50	3.42	2.36	2.88
1.000	4.47	5.81	3.63	4.40
2.000	7.68	8.85	5.73	6.63
4.000	12.33	13.57	8.20	8.71

TABLE XXVIII. BULK DENSITY, LB/CU FT, T-991, 2 OUNCE

Load Applied (psi)	As Received		Laundered	
	Initial	After Compression	Initial	After Compression
0.005	0.32	0.37	0.65	0.71
0.010	0.37	0.43	0.73	0.80
0.015	0.42	0.49	0.80	0.87
0.025	0.50	0.59	0.88	0.95
0.050	0.66	0.82	1.05	0.17
1.100	0.98	1.26	1.33	1.52
1.150	1.27	1.69	1.57	1.82
0.200	1.59	2.12	1.84	2.14
0.500	3.91	4.53	3.68	4.55
1.000	5.73	7.48	6.65	8.24
2.000	9.05	12.29	12.36	12.36
4.000	14.33	21.50	24.71	28.83

TABLE XXIX. BULK DENSITY, LB/CU FT, T-991, 3 OUNCE

Load Applied (psi)	As Received		Laundered	
	Initial	After Compression	Initial	After Compression
0.005	0.31	0.34	0.59	0.65
0.010	0.34	0.39	0.65	0.72
0.015	0.37	0.43	0.70	0.77
0.025	0.42	0.50	0.77	0.85
0.050	0.55	0.69	0.92	1.02
0.100	0.81	1.05	1.15	1.31
0.150	1.06	1.42	1.36	1.56
0.200	1.33	1.80	1.58	1.89
0.500	3.06	4.29	2.97	3.61
1.000	7.15	8.14	5.06	6.02
2.000	12.42	16.86	8.43	9.73
4.000	29.50	33.71	14.06	18.07

8. Investigation of Sewing Technique and its Effect on Shrinkage

A fiber blend of 50 percent Dacron Type 88 Fiberfil and 50 percent T-33 polypropylene was prepared and formed into a batting approximately 2 in. thick on the Davis and Furber sample cord. This particular blend was selected, since during previous sampling, a batting of this construction had shown considerable increase in weight-per-unit-area after laundering. The batting was subdivided and sewn into balloon fabric for launderability tests, with one sample arranged perpendicular to the direction of stitching and the other sample parallel to the stitching direction.

Table XXX shows the results of this experiment.

TABLE XXX. EFFECT OF SEWING TECHNIQUE ON SHRINKAGE

Position of Batting Relative to Stitching	% Increase in Weight per Unit Area after Laundering
Perpendicular	60.2
Parallel	48.8

The indications are that with channels 6 in. wide, it is preferable to sew battings into a sleeping bag in the longitudinal direction to reduce shrinkage. However, this is based on one observation only and further experimentation is necessary.

9. Conclusions

Various polyester fiber combinations when spray-bonded with acrylic emulsions have been found to satisfy the requirements of low bulk density, recovery from compression and resistance to laundering (when laundered in multiple layers). Larger quantities of the following three types of batting were prepared.

a. 90 percent mechanically crimped Dacron, 10 percent Regular Dacron Type 88 Fiberfil (Sample T-991).

b. 75 percent denier Kodel, 25 percent denier Kodel (Sample T-988)

c. 100 percent regular Dacron Type 88 Fiberfil (Sample T-990)

It is necessary to apply acrylic emulsions such as Nyanza T-15, Tecpol 115 of Rhoplex HA-16 at the 12.5 percent to 15 percent solids level in conjunction with the appropriate catalysts. Application by means of spray nozzles operating first on one side of the batting and then, after drying, on the reverse side, followed by curing, appears to be a satisfactory system of manufacture.

Fiber blending by means of a picker followed by carding produces a suitable web for spraying. However, the fiber combination consisting of 90 percent mechanically crimped Dacron and 10 percent regular Dacron Fiberfil appears to load the card wires to an excessive extent; webs with a weight in excess of three oz/sq ft could not be produced on the equipment available.

Air-laid webs appear to produce battings which show excessive loss of thickness after laundering, but additional work is required to establish the validity of this observation.

Needled battings are consistently higher in bulk density than corresponding spray-bonded battings and this system of manufacture must be considered extremely unpromising as a method of producing sleeping bag filling.

When battings are multi-layered to produce a thickness of approximately 2 in. at 0.01 psi pressure, thickness retention after laundering is satisfactory. When a single layer is laundered, shrinkage exceeds the specified maximum thickness loss of 20 percent; the loss is approximately inversely proportional to the batting weight per unit area.

10. Recommendations

An investigation of the phenomenon of the considerable loss in thickness after laundering of single-layer battings compared with the much lower loss for multi-layered battings would be worthwhile.

Further work on air-laid battings and investigation of the reasons for their greater thickness loss after laundering would also be desirable.

The effect of different sewing techniques and batting orientation on shrinkage and thickness loss is worth investigating.

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APPENDIX

NOTE ON CUBAGE AND CLO VALUE

The determination of sleeping bag cubage values is arbitrary since they are derived from measurements made on manually rolled-up bags. Obviously, different individuals will produce rolled-up bags of varying dimensions. However, the dimensions quoted in the text are the results of the same individual rolling all the bags under consideration.

The CLO is a unit of insulation and is the amount of insulation necessary to maintain comfort and a mean skin temperature of 92°F in a room at 70°F with air movement not over 10 ft/min., humidity not over 50 percent with a metabolism of 50 calories per square meter per hour. One CLO is equal to the insulating effect of 0.25 inch of still air. On the assumption that 76 percent of the body's heat is lost through the clothing, a CLO may also be defined in physical terms as the amount of insulation that will allow the passage of 1 cal/sq m/hr with a temperature gradient of 0.18°C between the two surfaces. Men's ordinary business clothing has an insulation value of about 1 CLO.

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13. ABSTRACT An investigation of lightweight, bulky batting-type filling material for sleeping bags involved the study of a wide range of fiber types, which were formed into webs by carding, garnetting and air-layering systems. The resultant webs were subsequently processed into battings by spray-bonding and needling. Needled battings were found to have a consistently greater bulk density than spray-bonded battings formed from corresponding webs.

From considerations of compressional recovery, low bulk density and resistance to laundering, polyester fibers in general were found to be the most satisfactory of all fibers examined, when spray-bonded with acrylic emulsions of the types Nyanza T-15, Tecpol 115 or Rhoplex HA-16. In particular, a blend of 90 percent mechanically crimped Dacron Fiberfil and 10 percent regular Dacron Type 88 Fiberfil showed promise as a filling for sleeping bags. However, practical problems were encountered when battings in excess of 3 oz/sq yd were required to be processed. A blend of 75 percent 4.5 denier Kodel and 25 percent 15 denier Kodel, and a batting of 100 percent regular Dacron Type 88 Fiberfil also showed promise and could be produced without much difficulty at the four weights specified, namely, 2,3,4, 5 ounces per square yard.

Picker blending followed by carding was found to be a satisfactory method of web formation, as air-laid battings tended to show a greater loss of thickness after laundering. Thickness loss after laundering was also found to be influenced by the batting weight per unit area. The lighter battings generally shrank to a greater extent than the heavier battings. However, for sleeping bag applications, multi-layering of battings is required to obtain a final thickness of approximately 2 inches at 0.01 psi pressure. Under these circumstances, loss in thickness after laundering is inhibited; in one instance, a trial sleeping bag was found to have increased in thickness after laundering.

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14. KEY WORDS	LINK A		LINK B		LINK C	
	ROLE	WT	ROLE	WT	ROLE	WT
Carding	8				6	
Garnetting	8					
Polyester fibers	1					
Rando webs	2		1		6	
Webs (sheets)	2		1			
Batting	4		2		9	
Sleeping bags	4		4		4	
Needling			8			
Spray bonding			8			
Laundering					6	
Thickness					7	
Picking (opening)					6	
Blending					6	
Weight (mass)					6	

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